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Swoogle: Showcasing the Significance of Semantic Search

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Abstract - **The World Wide Web hosts vast repositories of information. The retrieval of required information from the Internet is a great challenge since computer applications understand only the structure and layout of web pages and they do not have access to their intended meaning. Semantic web is an effort to enhance the Internet, so that computers can process the information presented on WWW, interpret and communicate with it, to help humans find required essential knowledge. Application of Ontology is the predominant approach helping the evolution of the Semantic web. The aim of our work is to illustrate how Swoogle, a semantic search engine, helps make computer and WWW interoperable and more intelligent. In this paper, we discuss issues related to traditional and semantic web searching. We outline how an understanding of the semantics of the search terms can be used to provide better results. The experimental results establish that semantic search provides more focused results than the traditional search.**

Index Terms – **Heterogeneous data, Linked Data, Data integration, RDF, Semantic Search, Semantic Web, Swoogle, OWL, Ontology, Web search, World Wide Web**

I. Introduction

The World Wide Web is a massive collection of vast repositories of information. The retrieval of required information from this ocean of knowledge is a great challenge. Computer applications can process only the structure and layout of web pages and they do not have access to their intended meaning. The Semantic Web addresses this problem and enables users to retrieve the relevant information from the Web by querying these heterogeneous data sources.

The Semantic Web [4] is meant to enhance the present form of the Internet and the World Wide Web through a layer of machine-interpretable metadata [14]. The emergence of the Semantic Web will simplify and improve knowledge reuse on the Web. The Semantic Web is built over a new model achieved through Resource Description Framework (RDF), eXtensible Markup Language (XML) [20] and Web Ontology Language (OWL).The Resource Description Framework's data model is adopted for modeling the web objects as part of developing the semantic web.

The remaining sections of this paper are organized into:

- Sections II to IV presenting an overview of ontology.
- Sections V and VI discussing about semantic search.
- Sections VII and VIII describing the semantic search framework and related algorithms.
- Section IX describing the details of Swoogle and the work done.
- Sections X and XI giving results and possibility of the outcomes.

II. Components of Ontology

Ontologies are used in order to support interoperability and common understanding between the different parties. They are the key component in solving the problem of semantic heterogeneity, thus enabling semantic interoperability between different web applications and services. Recently, ontologies have become a popular research topic in many communities, including knowledge engineering, electronic commerce, knowledge management and natural language processing. Ontologies provide a common understanding of a domain that can be communicated between people, and of heterogeneously distributed application systems. They are developed to facilitate knowledge sharing and reuse [13].

The goal of ontology is to achieve a common and shared knowledge that can be transmitted between people and application systems and achieving interoperability across organizations and on the semantic web[1]. Ontology is essentially built on the four main components- Concept, Instance, Relation and Axiom.

A) Concept

The "Concept" is an abstract group, set or collection of objects. It is the fundamental element of the domain and usually represents a group or class whose members share common properties. This component is represented in hierarchical graphs. The concept is represented by a "super-class", or "parent class", and a "subclass" or "child class" [2]. For instance, a "University" could be represented as a class with many subclasses, such as faculty, libraries and employees.

B) Instance

It is the "ground level" component of an ontology which represents a specific object or element of a concept or class [7]. They are the basic, components of ontology. The individuals in ontology may include concrete objects as well as abstract individuals. Facts are the terms commonly used to represent a relation which holds between instances.

C) Relation

It is used to express relationships between two concepts

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in a given domain. More specifically, it describes the relationship between the first concept, represented in the domain, and the second, represented in the range. For example, "study" could be represented as a relationship between the concept "person" (concept in the domain) and "university" or "college" (concept in the range).

D) Axiom

Axioms are assertions, including rules, in a logical form. They are normally used to represent knowledge that cannot be formally defined by the other components. They can be included in an ontology for several purposes, such as constraining the information contained in the ontology, verifying the consistency of the ontology itself or the consistency of the knowledge stored in a knowledge base, or deducting new information.

III. Structure Of Ontology

In general, structure of ontology[1] is described as

O: = (C, HC, R, HR, I)

where:

- ***C*** represents a set of concepts (instances of "*rdf:Class*")[15] These concepts are arranged with a corresponding subsumption hierarchy HC.
- ***R*** represents a set of relations that relate concepts to one another (instances of "*rdf:Property*"). Riõ R and Ri '! C × C.
- ***HC*** represents a concept hierarchy in the form of a relation (a binary relation corresponding to "*rdfs:subClassOf*"). The **HC(C_1, C_2)** denotes that $\mathbf{C_1}$ is a subconcept of $\mathbf{C_2}$.
- ***HR*** represents a relation hierarchy in the form of a relation **HR (R×R)**, where HR ($\mathbf{R_1}$, $\mathbf{R_2}$) denotes that $\mathbf{R_1}$ is a sub relation of **R2** ("*rdfs:subPropertyOf*").
- ***I*** is the instantiation of the concepts in a particular domain ("*rdf:type*").

Ontologies are classified in to two types as lightweight and heavyweight ontology [6]. The lightweight ontology includes concepts, concept taxonomies, relationships between concepts, and properties that describe concepts, while the heavyweight ontology adds axioms and constraints to the lightweight. These clarify the intended meaning of the terms gathered in the ontology. Heavyweight and lightweight ontologies can be modeled with different knowledge modeling techniques and can be implemented in various kinds of languages. Ontologies can be:

- *Highly informal:* if they are expressed in natural language; According to this, a highly informal ontology would not be ontology, since it is not machine readable.
- *Semi-informal:* if expressed in a restricted and structured form of natural language, since it is a machine-readable;
- *Semi-formal:* if expressed in an artificial and formally defined language (e.g. RDF graphs); and
- *Rigorously formal:* if they provide meticulously defined terms with formal semantics, theorems and proof of properties such as soundness and completeness (e.g. Web Ontology Language: OWL).

The expressiveness of ontology is based on the degree of explication of the (meta) knowledge [4]. The expressiveness of ontology is restricted by the languages used for describing or specifying it [3]. Ontology is expressed in a knowledge representation language, which provides a formal frame of semantics. This ensures that the specification of domain knowledge in an ontology is machine-process able and is being interpreted in a well-defined way.

IV. Ontology in Diverse Fields

Over the years, ontology has become a popular research topic in a range of disciplines, with the aim of increasing understanding of and building a consensus in a given area of knowledge. Ontology also leads to the sharing of knowledge between systems and people. It is used in fields such as,

A) Semantic Web

Ontology plays a key role in the Semantic Web for supporting information exchange across distributed environments[5]. The Semantic Web represents data in a machine process able way, which is why it is considered to be an extension of the current Web.

B) Semantic Web Services Discovery

In the e-business environment, ontology plays an important role by finding the best match for the requester looking for merchandise.

C) Artificial Intelligence

Ontology has been developed in the AI research community. Its goal is to facilitate the sharing of knowledge and the reuse of components. It enables the processing between programs, services, agents or organizations across a given domain.

D) Multi-agent

The importance of ontology in this area is that it provides a shared understanding of domain knowledge, allowing for easy communication between agents and thereby reducing misinterpretations.

E) Search Engines

These use ontology in the form of thesauri is to find the synonyms of search terms, which in turn facilitates internet searching.

F) E-Commerce

This application uses ontology to facilitate communication between seller and buyer through the description of merchandise, as well as enabling machine-based communication.

G) Interoperability

The problem of bringing together heterogeneous and distributed systems is known as the "interoperability problem". It is used to integrate different heterogeneous application systems [13].

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V. Semantic Search

Semantic search is an application of the Semantic Web to search for the appropriate document. Searching is one of the most popular applications on the Web and an application with significant room for improvement [15]. The addition of explicit semantics will improve search. As with the WWW, the growth of the Semantic Web will be driven by applications that use it[10]. Semantic Search attempts to augment and improve traditional search results, based on Information Retrieval technology, by using data from the Semantic Web.

Traditional Information Retrieval (IR) technology is based almost purely on the occurrence of words in documents. Search engines like Google, augment this in the context of the Web with information about the hyperlink structure of the Web .

The availability of large amounts of structured, machine understandable information about a wide range of objects on the Semantic Web offers some opportunities for improving on traditional search. Before getting into the details of how the Semantic Web can contribute to search, an overview of two very kinds of searches is presented.

A) Navigational Searches

In this class of searches, the user provides the search engine a phrase or combination of words which the user expects to find in the documents [4]. There is no straightforward, reasonable interpretation of these words as denoting a concept. In such cases, the user is using the search engine as a navigation tool to navigate to a particular intended document.

B) Research Searches

In many other cases, the user provides the search engine with a phrase which is intended to denote an object about which the user is trying to gather/research information. There is no particular document which the user knows about that user is trying to get to. Rather, the user is trying to locate a number of documents which together will give user, the information he is trying to find. These type of searches are focused in the present work [9].

Example: A search query like "SEMANTIC WEB" does not denote any concept. The user is likely just trying to find the page containing all these words. On the other hand, search queries like "JACK" or "USA", denote a person or a country. The user is likely doing a research search on the person or place denoted by the query. Semantic search attempts to improve the results of research searches in 2 ways.

Traditional search results take the form of a list of documents/Web pages. This work augmented this list of documents with relevant data pulled out from Semantic Web [22]. The Semantic Web based results are independent of and augment the results obtained via traditional IR techniques. So, for example, a search for A. R. Rahman might get augmented with his current concert schedule, his music albums, his image, etc

VI. Advantages of Semantic Search Over Traditional Search

A) Tenses and Plural forms

Semantic search can handle morphological variations like tenses, plural forms very easily. This means when the user type words like write, written, writing or writes will all lead to exactly same page [14]. There will be no difference between "how to write an article?" or "writing an article."

B) Synonyms with correct meaning

In semantic search similar results will be shown for synonyms which match with the current context. People may consider words like cure, treat or heal as synonyms so results yielding to "cure for cancer" will be same as results to "treat/treatment for cancer" and "heal for cancer." However the word treat have two different meaning the sematic search index has a fair algorithm to differentiate between the two words and put in the right meaning for the current context.

C) Generalization [12]

Semantic search will have a set for generalization for particular category. For example the word cricket has answers like Sachin Tendulkar, Ricky Ponting, Murilitharan and so on. When a query is asked such that "who is the leading run getter in ODIs?" the answer should be Sachin Tendulkar in semantic search rather than showing many web pages. This reduces the complexity faced by us in traditional search index which is mostly based on the ranking of the page. Search engine system is different from that of question answering system. In search engine we get all the web related pages and documents which are top ranked whereas question answering system yields a single result which best describes the query typed by the user from set of answers available in the semantic search.

D) Concept Matching [12]

This is one of the most promising tasks of semantic search. Semantic search gets all the possible results which are similar to the query concept are displayed. Suppose if the user gives a query as a "How to install Windows 7?" the search comes out with results like installing windows 8 consumer preview as it is the advanced version of Windows 7 and people may have a look at it.

E) Knowledge Matching

This is quite similar to the previous one i.e., concept matching. When the user types a phrase related to Microsoft Windows, it tries to bring out all the best possible results for Microsoft Windows which best suits for the current context from the pool of knowledge bits present in semantic search.

F) Ability to figure out the most relevant sentence for the current query

Semantic search not only picks up the relevant web page but also has the ability to figure out the exact paragraph from a huge content. Suppose there is huge content related to features of Apple iPad-5 which describes about its processor,

camera, apps, face time and other related features. Now a user types a query as “what is the processor in Apple iPad-5?” then the semantic search will directly point to paragraph which describes the processor of iPad-5 making the work easy.

G) Ability to operate without any artificial means

Semantic search is independent of artificial means like ranking of the page, keywords or tags and depends on more of the contextual meaning of the query . Its ability to understand the query may not compete with human brain but can come close to the human brain of thinking to certain extent. Since semantic search doesn’t depend on any artificial means its search results are more of real time results.

VII Framework Of Semantic Search

The framework adopted for the semantic search is shown in the Fig.1. The data acquisition component provides different solutions for collecting unstructured (ex: web pages), semi-structured (ex: data in XML), structured (ex: data in database), and structured semantic data (ex: existing RDF datasets and RSS feeds). The collected unstructured and semi structured data needs to be transformed to structured data using certain processing techniques defined in the knowledge acquisition component.

Methods used for acquiring knowledge in semantic Web applications fall into mainly two categories such as Conversion-based methods and Ontology Learning. Conversion-based approaches refer to those transform semi-unstructured data into structured data according to pre-defined schemas. It is effective when large amount of semi-structured data and well defined schemas are available. However, there are some problems associated with approaches of this kind which prevent them being efficiently deployed. For example, Conversion-based approaches do not provide broad coverage of some domains; in some application domains semi-structured data may not be available or data publishers are not willing to publish such data due to proprietary concerns.

Moreover, approaches of this class are not able to generate structured data from unstructured data. Research in ontology learning provides promising solutions for generate structured data, or ontologies, from unstructured text with tolerable error rates. The assumption is that given sufficient large amount of text in a domain, coverage of knowledge in that domain can be ensured. As a consequence, the problem of “knowledge acquisition bottleneck” can be alleviated to a great extent. For example, hidden knowledge, which is essential for applications such as expert finding and concept hierarchy construction while is difficult to observe, could be obtained using some sophisticated inference techniques in an automated fashion.

The data integration and consolidation component summarizes solutions for a problem arisen from the knowledge acquisition process, which is the fact that different sources may publish different and often complementary data on same entities.

The various Semantic Search Mechanisms such as Ranking and Searching Algorithms are widely used to obtain the relevant documents. The different Semantic Search services are provided to retrieve the document in a specific order and presented in a specific format as depicted in Figure 1.

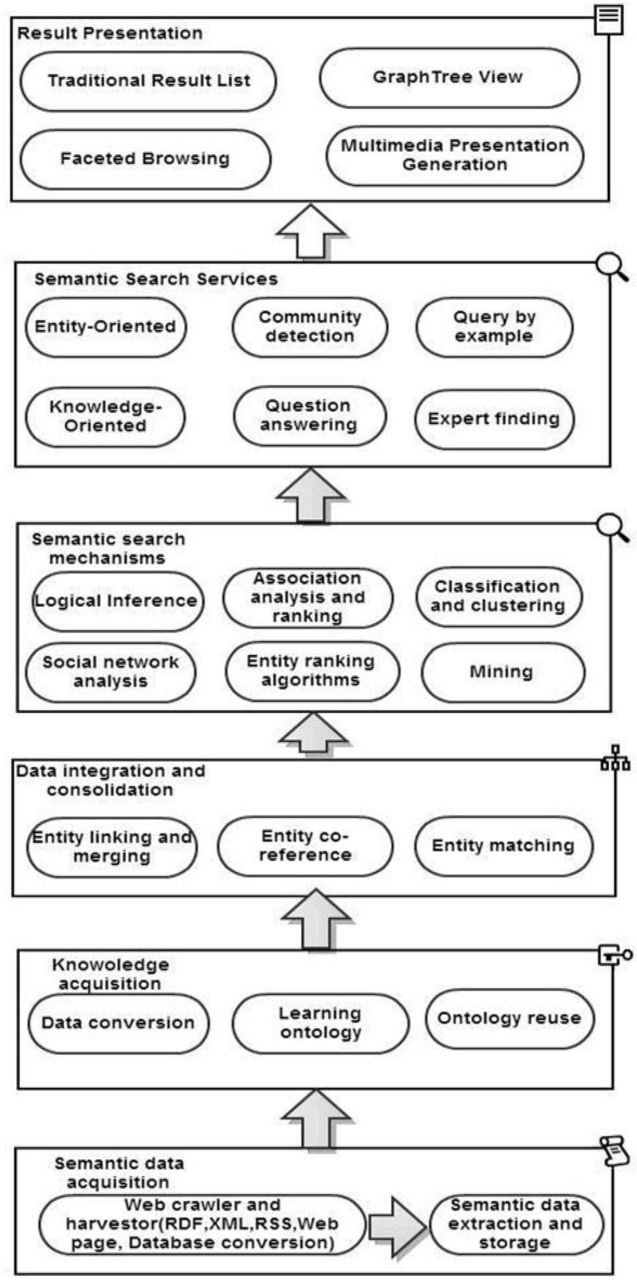


Fig 1: Framework for semantic search

VIII. Ontology Ranking

The search engines play a vital role in retrieving the information from the World Wide Web. But, the web pages which are retrieved may contain ineffective and irrelevant information. The semantic web architecture overcomes this limitation by applying the ranking algorithms. The ranking algorithm extract the information based on the user queries from the semantic search engine and provides the desired result.

The following ranking algorithms are used in Semantic web.

- Content-based Ontology ranking algorithm
- OntoRank Algorithm

A) Content-based Ontology Rank Algorithm

The content-based ontology ranking algorithm obtains a list of ontologies from a search engine, based on the internal structure with content similarity of the ontology related with corpus. Based on the term given by the knowledge engineer, the retrieved ontologies are ranked. The ranking is done according to the number of concept labels in those ontologies which matches a set of terms extracted from a WordNet. It is done related to the domain of knowledge identified by the knowledge engineer's original search terms.

The content-based ontology rank algorithm ranks the ontology by extracting the query terms related words through the WordNet along with the four measures [8]:

***i)** Class Match Measure (CMM):* Evaluates the coverage of ontology for the given search terms. An ontology that contains all search terms will obviously score higher than others, and exact matches are regarded as better than partial matches. In the class match score, each ontology matches with class labels and in the literal text match score, the literal text like comments are matched with the class labels.

$$CMS = [o \in O] = \sum_{i=1}^{N} I(Pi, o) * 5 \log(n + 2 - i)$$

Total= α * CMS + β * LMS

Where O = set of ontologies to be ranked

Pi = set of potential class labels obtained from the corpus.

n = number of terms collected from corpus.

α and β are the weight factors.

The ontology which has more class labels matches the words in the corpus and is ranked higher than the others.

ii) Centrality Measure (CEM): Studies showed that mid hierarchical level concepts tend to be more detailed and prototypical of their categories than classes at higher orlower hierarchical levels [7]. CEM measures how close a concept is placed to the middle level of its hierarchy.

iii) Density Measure (DEM): When searching for a "good" representation of a specific concept, one would expect to find a certain degree of detail in the representation for the target concept. This may include how well the concept is further specified, how many attributes and siblings the class has, etc. DEM is intended to approximate the representational-density of classes and consequently the level of detail for concepts.

iv) Semantic Similarity Measure (SSM): This measure calculates the semantic similarity between the classes that were matched in the ontology with the search terms. The motivation here is that it might be preferred for the search terms to be closely related to each other in the ontology than otherwise. SSM formula is based on the shortest path measure [8].

B) OntoRank Algorithm

Based on semantic web link structure which gives priorities for different link relationship (Fig.2), the OntoRank algorithm [21] applies the link analyze method. Here two concepts are considered as a reference relationship if and only if a relationship exists between the two classes in a relation set.

The algorithm is:

OntoRank a = $wPR(\alpha)+\sum_{x \in O\,TC(a)} wPR(x)$

Where, wPR (α) = accessed probability of Semantic Web document (SWD) of 'a' of itself.

$\sum_{x \in OTC(a)}$ wPR(x)=accessed probability of all imported SWD.

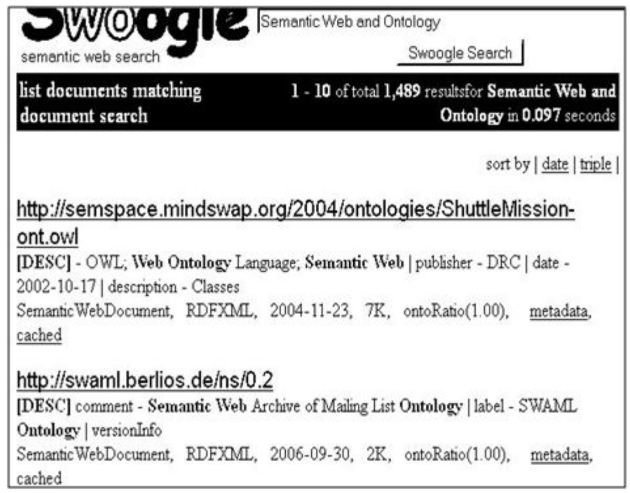


Fig 2: Semantic Search - sort by OntoRank

IX. Semantic Searching With Swoogle

Swoogle, a semantic search engine for the evolving Semantic web, primarily uses the metadata [14] [16] that is collected from the appropriate Semantic Web Document (SWD). This facilitates speedy, appropriate and efficient Semantic Web search. The metadata is derived from the content of SWD and relations between Semantic Web Documents. The three categories of the metadata are:

a) *Basic Meta data*: It considers the syntactic [17] and semantic features of a Semantic Web Document.
b) *Relations:* It considers the explicit semantics [17] between different Semantic Web Documents.
c) *Analysis Result:* It includes SWO/SWDB classification and SWD ranking.

A) Basic Metadata

The Properties which are directly related to the Semantic Web Document are:

- Language features
- RDF statistics
- Ontology annotations

i) Language features: It refers to the syntax and semantics of a SWD [3]. The language features listed below, form the foundation of the semantic web document.

Encoding: It indicates the syntactic encoding of a SWD. The two types of encoding are

- RDF/XML
- N3

Language: It indicates the semantic language used by a SWD. The four types of languages are:

- OWL
- DAML+OIL
- RDFS [19]
- RDF

OWL Species: It is specific to OWL documents and gives the genre of OWL used [18]. The OWL species are:

- OWL
- OWL-LITE
- OWL-DL
- OWL-FULL

ii) RDF statistics: It refers to the properties of the node distribution in RDF graph [9]. We focus on how Semantic Web Documents define new classes, properties and individuals. In an RDF graph, a node is identified as a class and it is an instance of rdfs: Class: similarly, a node is a property and it is an instance of rdf: Property. Instance of any user defined class is termed as individual node.

iii) Ontology annotations: The properties that describe Ontology are indicated by the annotations. In practice, when a SWD is written in OWL [3] and has an instance of OWL: Ontology. The record is created by using the following properties

- Number of imports
- Version Info.
- Comment.
- Label.

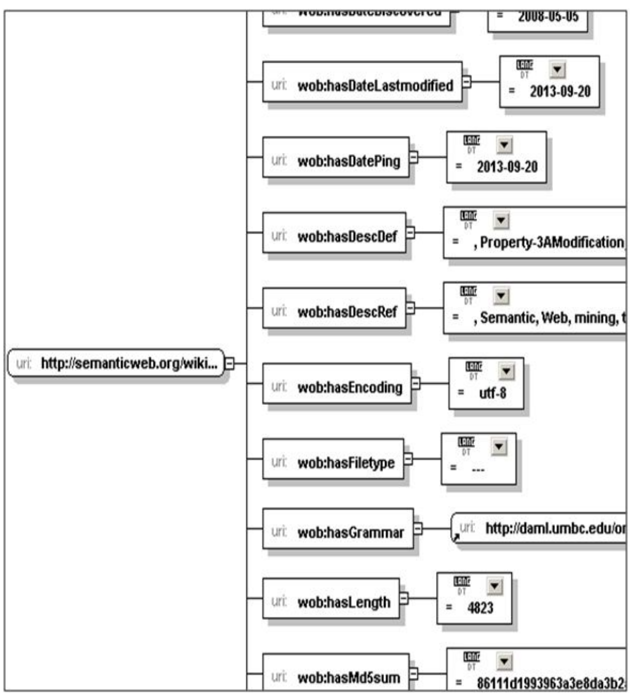


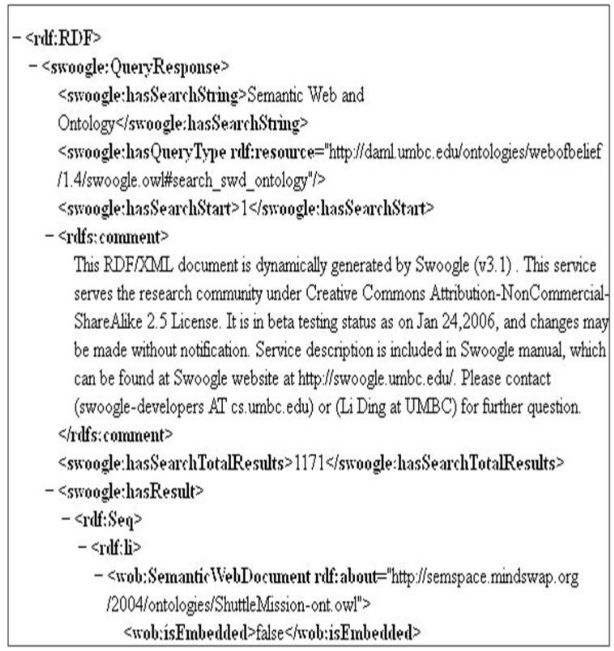
Fig 3: RDF Graph for "semantic web and ontology" search

Resource Description Framework (RDF) is a graphical representation (Fig.3) of information in the Semantic Web Document. Information is represented by triples subject-predicate-object in RDF. Resource Descriptor Framework and the triple patterns are used in our related work. Turtle is an extension of N-Triples [4] [21].

The three parts of the statements are:

- Subject
- Predicate
- Object

The subject is the first part of an RDF statement (Fig.4) that identifies the Web resource that is being described by the RDF entry. The predicate is the second part of an RDF statement. It defines the property for the subject of the statement. The object is the third part of an RDF statement. Object is referred as a property value that is mapped to a subject by the predicate.



```
- <rdf:RDF>
  - <swoogle:QueryResponse>
      <swoogle:hasSearchString>Semantic Web and
      Ontology</swoogle:hasSearchString>
      <swoogle:hasQueryType rdf:resource="http://daml.umbc.edu/ontologies/webofbelief
      /1.4/swoogle.owl#search_swd_ontology"/>
      <swoogle:hasSearchStart>1</swoogle:hasSearchStart>
    - <rdfs:comment>
        This RDF/XML document is dynamically generated by Swoogle (v3.1) . This service
        serves the research community under Creative Commons Attribution-NonCommercial-
        ShareAlike 2.5 License. It is in beta testing status as on Jan 24,2006, and changes may
        be made without notification. Service description is included in Swoogle manual, which
        can be found at Swoogle website at http://swoogle.umbc.edu/. Please contact
        (swoogle-developers AT cs.umbc.edu) or (Li Ding at UMBC) for further question.
      </rdfs:comment>
      <swoogle:hasSearchTotalResults>1171</swoogle:hasSearchTotalResults>
    - <swoogle:hasResult>
      - <rdf:Seq>
        - <rdf:li>
          - <wob:SemanticWebDocument rdf:about="http://semspace.mindswap.org
            /2004/ontologies/ShuttleMission-ont.owl">
              <wob:isEmbedded>false</wob:isEmbedded>
```


Fig 4: RDF Structure of Semantic Search

An RDF graph [9] is a set of RDF triples. If G is an RDF graph (Fig. 5), term (G) is the set of elements of T appearing in the triple of G, and blank (G) is the set of blank nodes (Fig. 6) appearing in G, i.e. blank (G) =term (G $\cap$ B

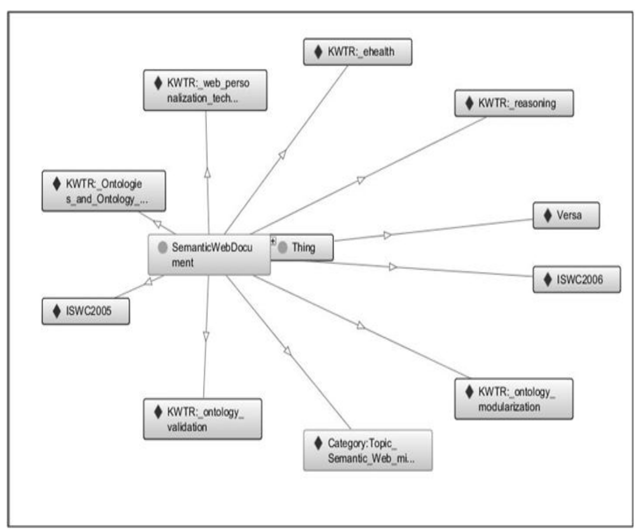


Fig 5: Searching for "SEMANTIC" in the Ontology

RDF parser [4] would return the data contained in this document in its triplet form as in Table 1. shown below

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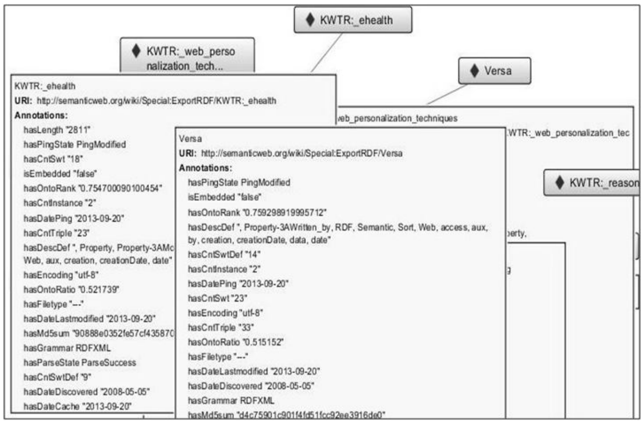

Fig 6: Semantic Search - Pin Node Tips

TABLE I. REPRESENTATION OF N –TRIPLES

Subject	Predicate	Object
G:\DEMO\SPARQL	http://www.w3.org/1999/02/22-rdf-syntax-ns# - name	Jack
G:\DEMO\SPARQL	http://www.w3.org/1999/02/22-rdf-syntax-ns# - dept	IT
G:\DEMO\SPARQL	http://www.w3.org/1999/02/22-rdf-syntax-ns# - price	Software Engineerin g
G:\DEMO\SPARQL	http://www.w3.org/1999/02/22-rdf-syntax-ns# - spec	45100

X. RESULTS

The experimental results for the above Semantic Web Search were done by ranking algorithms obtaining the relevant ontologies from the Swoogle for the search term “semantic web and ontology”. Table 2 lists search results for the sample terms and the search criteria viz., Sort:Date, Sort:OntoRate and Sort:N–Triples.

By using the Swoogle Semantic search 1,171 results (Fig.7) for the term “semantic web and Ontologies” are obtained in 0.089 seconds, but in the Google search 4,390,000 results are obtained in .029 seconds for the same search term.

Fig 7: Semantic Web Search - 1171 documents in 0.086 sec.

The ranking techniques are applied on these Ontologies [11]. The results obtained in number of related documents are tabulated in Table 2. The graphical chart for all the various search constraints along with results obtained is given in Fig.8. Here the X-axis denotes the components and the Y-axis denotes the corresponding values based on the results obtained.

TABLE: II COMPARISON OF TRADITIONAL AND SEMANTIC SEARCH

Components	Traditional Search Results	Semantic Search Results
Term: SW and Ontology	4,390,000	1171
Sort : Date	3,360,000	1171
Sort : Ontorate	2,490,000	1171
Sort : N – Triples	1,680,000	1171

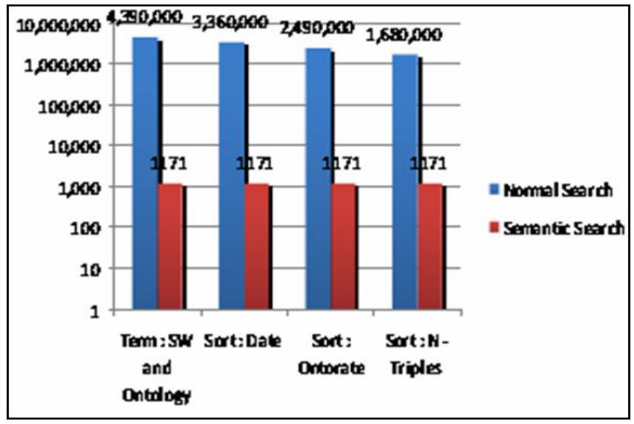

Fig 8: Comparison of Traditional and Semantic Search

XI. CONCLUSION

The trouble of sifting through a million pages, most of it with little relevance, is daunting for anybody. Like the World Wide Web, the Semantic Web is decentralized and is built by the community. Swoogle is a crawler-based indexing and retrieval system for the Semantic Web of documents. The Swoogle extracts metadata for each discovered document. The discovered documents are also indexed by an information retrieval system which finds relevant documents and computes the similarity among the set of documents. Instead of hard coding knowledge inside intelligent agents, the semantic web enables agents to publish and consume knowledge explicitly stored in web documents. With more content being put on the SWD, researchers and the general web users are more likely to migrate towards semantic web. The above results prove that in traditional search, the number of retrieved documents are very high with lesser relevance, whereas in the Semantic Search, the degree of relevance of the documents are higher with lesser number of documents being retrieved. This reduces the clutter and renders the process of getting relevant data and subsequent information more meaningful.

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